STRUCTURE OF THE SEYFERT BROAD LINE REGION AND ABSORPTION REGION OF NGC 4151

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BACKGROUND

We have monitored the Seyfert nucleus of NGC 4151 for six years, including periods of intensive study of the complex variations in the ultraviolet spectrum with IUE, and some co-ordinated optical and X-ray observations. Here we briefly review important IUE results relating to the structure of the Broad Line Region and its physical conditions. Our detailed analyses and results are published in a series of papers, viz: Penston et al 1981 (Paper I: initial IUE results); Perola et al 1982 (Paper II: continuum); Ulrich et al 1984 (Paper III: broad emission lines); Bromage et al 1984 (Paper IV: absorption line region); Snijders et al 1984 (Paper V: atlas and survey). A further paper (VI) on the very low luminosity state of the nucleus, is in preparation. A brief pictorial review of the low-dispersion IUE data and implications can be found in proceedings of the 1982 Madrid IUE Conference (Bromage et al 1982).

Unravelling the complexities of the NGC 4151 IUE spectra to derive the valuable physical information on the BLR has necessarily involved a substantial amount of observing time - for improving signal-to-noise ratios; for observing at high resolution; for establishing timescales of the many variability phenomena; for long-term monitoring; and for the key, intensive following of any outbursts. The main aim of such studies of Active Galactic Nuclei is to derive detailed constraints on radiation mechanisms and physical conditions in the emission region, and hence also constraints on possible central power sources. We would maintain that this can best be achieved by intensive study of a few key AGN's like NGC 4151 - not only with IUE but, a fortiori, with HST and future ultraviolet and X-ray experiments.

RESULTS

The ultraviolet spectrum of NGC 4151 comprises continuum, strong emission lines with different widths, and a rich absorption line spectrum. All components vary (Paper I), with the fastest changes occurring on a timescale of some 5 days. The continuum is most simply represented as a power law together with (at many, but not all, epochs of observation) an additional

component seen as a 'far UV excess'. The power law component hardens as it brightens, with an index of - 3 when the λ2500Å flux is only 5 mJy, and - 1.5 at 20 mJy. This power-law component appears to drive the changes in emission and absorption lines, suggesting that the additional component is weak in the far EUV and thus may be thermal emission - perhaps from an accretion disk in the centre (Paper II).

From the variability timescales and time-lag information for various emission lines, and from their velocity coverage, a partial stratification of the BLR into at least 3 zones is indicated (Paper III). The behaviour is broadly consistent with a black hole/accretion disk scenario with a central mass of $10^{8.0 - 8.5}$ solar masses. The variability data suggest a chain of cause and effect: events are first seen in the 'thermal' continuum component (fuel supply), later in the power law continuum, and last in the emission lines.

Variations in the 'broad' absorption lines seem to derive principally from changes in column densities of absorbing species rather than in velocity dispersions or line profiles (Paper IV). High dispersion profiles and low dispersion doublet-ratios imply a roughly constant effective b-value of some 500 kms^{-1}. The total velocity range is - 1100 to + 100 kms^{-1} approximately (relative to the narrow line region of NGC 4151). Our results suggest a model with large numbers of outflowing absorbing clouds that are almost optically thin. Information collected on space densities (mainly from metastable absorbers), on velocities covered, and on the lack of time lags, together point to most absorption's occurring in a thin shell in the outermost parts of the BLR.

The far-ultraviolet continuum of NGC 4151 has varied by nearly 3 magnitudes during IUE's lifetime. Recently it has been at its lowest recorded UV luminosity, and a large outburst is overdue! Such an occasion would provide a golden opportunity for further unravelling of the BLR structure and constraints on models for the central powerhouse - especially if simultaneous UV and X-ray observations are obtained throughout the outburst.

REFERENCES

Bromage G E et al 1982, ESA SP-176, p 533
Bromage G E et al 1984, MNRAS (to be published) (Paper IV)
Penston M V et al 1981, MNRAS 196, 857 (Paper I)
Perola G C et al 1982, MNRAS 200, 293 (Paper II)
Snijders M A J et al 1984, in preparation (Paper V)
Ulrich M H et al 1984, MNRAS 206, 221 (Paper III)